IMPACT OF COAL SMOKE POLLUTION ON GROWTH AND MORPHOLOGY OF CERTAIN ANNUALS

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BY

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C E R T I F I C A T E

It is my pleasure to certify that the dissertation entitled "IMPACT OF COAL SMOKE POLLUTION ON GROWTH AND MORPHOLOGY OF CERTAIN ANNUALS" has come to shape due to the genuine and sincere efforts made by **Mr. Mustafa Kamal Ansari** under my supervision. This may be submitted to the Aligarh Muslim University in candidacy for the award of M.Phil. degree in Botany.

Iqbal

(MUHAMMAD IQBAL)

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C O N T E N T S

INTRODUCTION

INTRODUCTION

Pollution means the presence of undesirable substance in any segment of environment primarily due to human activity discharging bye-products, waste products or harmful secondary products, that are harmful to man and other organisms. But in the scientific sense no environmental component is pure even in natural state. Though in insignificant amounts and not sufficient for any appreciable harm, there may be several admixtures and impurities in nature.

The quality of our environment has been constantly degrading and the stocks of non-renewable resources are decreasing fast. This is leading to extinction of wildlife, loss of gene pool, exhaustion of fossil fuel and mineral wealth, pouring in of toxic chemicals including many non-biodegradable ones in soil, water and air. The survival of man depends on how judiciously he manages the earth and maintains the quality of his overall environment. Admittedly, our genetic make-up cannot change to adapt to the fast-changing and pollutive environment such as rise of carbon dioxide, or reduced oxygen content in the air. We are arriving at limits of tolerance on most fronts and any greater onslaught would result into mass scale sudden deaths or disease, disablement and crippling and slow death of people. Man has now no option other than to fight seriously for the cause of sustained quality of his environment and natural resources; unitedly and at all levels i.e. at individual, community state, government, continental and global levels. Most developed as well as developing nations have taken up the environmental protection aspects seriously. Many underdeveloped countries over-exploit their natural wealth for short term gains and in the process cause desertification and pollution. The U.S. Government has enacted laws to check such destruction of nature and the natural environment. In France, Germany, India, Japan, U.K., USSR and many other countries, there is a trend of mass movements and hundreds of groups are active for environmental protection. In India, there is a separate ministry to look after the Environment, Forest and Wild-Life. There are central and state Pollution Control Boards to enforce antipollution laws and prevent pollution. The Environmental Education Conference held at Tbilisi, USSR in 1977 had identified its ultimate aim as creating awareness, behavioural attitudes and values directed towards preserving the biosphere, improving the quality of life everywhere, safeguarding ethical values and the cultural and natural heritage, including holy places, historical landmarks, works of arts, monuments and sites, human and natural environment, including fauna and flora and human settlements. Environmental education has to be regarded as a life long phenomenon rather than a school or college curriculum done. It has to be field-oriented and practical rather than through books only.

The developmental activities all over the world have widely altered the environmental quality at micro, macro and global levels. Also, a little negligence often leads to heavy disasters such as the Bhopal tragedy in India (Dec. 3, 1984) due to leakage of methyl isocyanate gas in the Union Carbide Factory that killed thousands, and rendered many more sick and blind. Another recent event of air pollution disaster is the chernobyl accident (26 April 1986) in which an explosion in the nuclear reactor led to an uncontrollable fire, lifting a vast amount of radionucleoid high into the atmosphere and exposing 400 million people in 15 nations of Europe (Elsom, D. 1987). Hawkes et al (1986) estimate the approximate number of death in the Soviet Union to be between 5,000 to 10,000. It is claimed that as many as a million people in the northern hemisphere may develop cancer as a result of Chernobyl accident and half of these cancers would be fatal. Several disasters are on the record due to leakage of lethal gases, poisoning of water by toxic chemicals, landslides, erosions, rapid sitting of dams, mass scale eradication of trees and wildlife through ecological back-lashes for unplanned developmental activities.

The organic fuel burnt at the thermal power stations contains harmful impurities which are ejected into the environment as gaseous and solid components of cumbustion products and adversely affect the whole biosphere. The atmosphere is also contaminated by waste gases of various industrial plants, exhaust gases of transport vehicles, abuse of agricultural chemicals and other contamination sources which are due to man's activities.

In India, by the turn of the century, about 70,000 MW of thermal power will be generated using high ash content coal. The environmental pollution due to thermal power generation will increase beyond acceptable limits unless stringent measures based on environmental protection act, 1986, are strictly enforced.

The thermal power stations use thousands of tonnes of low quality (high ash content) coal per day. These power stations and other industries have completely changed the nature and socio-economic order of the region. A fact finding committee constituted by the Ministry of Energy, Govt. of India (1987) reported that the activities of thermal power stations and other industries are involved in the concurrent environmental degradation by bellowing thick smoke from the chimneys and the generation of dust. The products of complete burning of fuel in thermal power plants mainly consist of Co_2, water molecules, N_2, SO_2 and SO_3 anhydride and ash. At high temperature existing in the flame core of high-power boilers, the nitrogen of fuel and air may partially be oxidised to form nitrogen-oxides. NO_2 dissociates in the presence of sunlight to nitric oxide and atomic oxygen. The atomic oxygen combines with molecular oxygen to form ozone.

The atmosphere is the gaseous cover on the surface of earth. Essentially it consists of a mixture of gases, principally nitrogen (79%) oxygen (21%) and carbon dioxide (0.03%) mixed with water vapour, and is called air. The gaseous mass constituting the atmosphere is estimated to be 5.15×10^{15} tonnes (Sytnick 1985). It also contains numerous other gases in traces and the floating particulate matter such as dust, pollen grains and micro-organisms. The air that is free from industrial or urban influences is taken to be relatively pure, mainly because the concentration of numerous admixtures is very low and they do not cause pollution. When foreign materials emitted from industrial chimneys, dumps of decomposing wastes, and various kinds of engines and automobiles are mixed in the "pure" air, the latter loses its purity and becomes "polluted". We can regard atmospheric pollution as a social disease affecting the entire society irrespective of status, age, caste, creed, profession or political affiliations. In the process of industrial and economic development man tends to see the economic returns and facilities generated but ignore or develop a blind spot towards this ecosystem disease until it reaches the alarming proportion and results into epidemics. The air that exists inside the soil between the particles and inside the plant body also forms an important component of the atmosphere in ecological sense. Atmosphere is the source of Co_2, the essential requirement for photosynthesis, and oxygen, the need of all cells to perform the life processes. The atmosphere is also the store house of the inert gas nitrogen which on biological and electrochemical fixation gets converted into ammonium and nitrate forms and is used in the synthesis of proteins. The moisture present in the form of invisible water vapour or humidity influences plant metabolism particularly the transpiration.

<u>Constituents gases</u>:

The dry air contains:

Nitrogen	78.084%
Oxygen	20.9467%
Argon	0.934%
Carbondioxide	0.0314%
Neon	0.0018%
Helium	0.0005%
Methane	0.0002%
Krypton	0.0001% and

small traces of H_2 , Xe , O_3 , NH_3 , Co and Iodine (Sytnic, 1985).

<u>Nitrogen</u>: This gas is inert and does not readily take part in chemical reactions under ordinary conditions. However, this is an essential constituent of chlorophyll and proteins. Plants get nitrogen in the form of nitrates and ammonium ions after the atmospheric nitrogen gets converted into these forms by the biological and electrochemical fixation. Nitrogen-rich fertilizers sometimes get lost from the agroecosystem and reach ground water through infilteration and rivers through run off. High nitrate in drinking water is a serious pollution problem caused due to excessive use of fertilizers beyond the level that crops may be able to utilize.

<u>Oxygen</u>: Oxygen content was very low in geological past and it has gradually increased through the Palaeozoic, Mesozoic and Coenozoic eras due to high rate of photosynthesis. Man has evolved in the high-oxygen-status period and is adapted most

favourably to this level. Decrease in oxygen causes serious respiratory problems and under prolonged poor oxygen level conditions death occurs. However, this high level (21%) is not optimum for best plant growth. Industries burning fossil fuel, automobiles, train engines and aeroplanes all use oxygen and release carbon dioxide in the air. In the community respiration, the volume of oxygen is utilized and carbon dioxide released. The balance is getting adversely affected due to decrease in oxygen and increase in carbon dioxide contents in the recent past. Ozone ultraviolet radiation of the sun. Increased ultraviolet radiation reaching the earth's surface because of thinning or rupture of the ozone layer would create serious health hazards such as skin cancer. High carbon dioxide concentration in soil atmosphere has a toxic effect. Many of the essential trace elements present in soil fail to be absorbed in high CO_2 soil atmosphere and the plants suffer from nutrient deficiency. The quantity of carbon fixed by green plants annually on global scale ranges between $4\text{-}9 \times 10^3$ kg.

<u>Air Pollutants</u>: Carbon dioxide, carbon monoxide, nitrogen oxide, nitrogen dioxide, sulphur dioxide and hydrogen flouride are the commonest gaseous pollutants. Nuclear fuel releases radioactive contaminants. The air pollutants are:

1) Gaseous: e.g. i) carbon monoxide and carbon dioxide,
ii) hydrocarbons i.e. carbon and hydrogen containing compounds, oxygenated hydro-

carbons through incomplete cumbustion of fuel.

iii) Sulphur compounds like sulphur dioxide and sulphur trioxide emitted by the burning of sulphur containing coal and other fuel and secondary formed hydrogen sulphide and sulphuric acid.

iv) nitrogen oxides and other nitrogen compounds like N_2O, NO, NO_2 and NO_3.

v) ozone which is useful at higher level of atmosphere as a protective sheild but is a harmful pollutant at lower levels in the human environment, and other oxidants and hydrogen fluorides. Many of these directly harm living beings, and others cause green-house effect or warming up of the atmosphere.

2) Particulate: eg. small to very small particles that keep floating in the air. Particles around one micron size present in air in the form of solid or liquid are called "aerosol". Particles smaller than aerosol assume the appearance of smoke and fumes, while the larger than them form dust if the particles are solid, or mist if they are liquid droplets. The particulate pollutants include living types such as bacteria, pollen grain, fungal and other spores, and nonliving ones, mostly emissions from man-made sources like burning of coal, oil and wood (ash),

chemical compounds formed from metallurgical industries lead combined with chlorine and bromine etc.

<u>Carbon monoxide</u>: Carbon monoxide (CO) is formed by incomplete combustion of fossil fuel and accounts for about half of the total air pollutants added to atmosphere. Major sources of CO pollution in cities are automobiles, oil refineries metallurgical operations and other internal combustion engines. In Calcutta city, 450 tonnes of CO are discharged every day. In USA alone more than 65 million tonnes of CO are emitted annually. Vegetation is regarded as a natural sink for CO pollution. The annual global input of this toxic gas is 6×10^4 g or 6000000000 tonnes (see Smith, 1984). Most of this emission is directly from anthropogenic sources. Highly industrialised countries like Japan, Korea, USSR, U K , France, Germany, USA and Canada lie in the northern hemisphere in temperate belt, so the CO pollution is most serious there. It is higher in winter than summer. CO, a colourless and odourless gas, is highly toxic if inhaled in sufficient quantities. It gradually gets oxidised to CO_2, it is not a long range global threat, but locally, in busy market areas its level rises alarmingly during peak emission period and causes serious health problems.

<u>Carbon dioxide</u>: The burning of fossil fuel also results in production of carbon dioxide and the destruction of forests reducing the carbon dioxide absorbing capacity of nature. CO_2 level is rising due to its higher release and lower utilization. It has

the green-house effect warming up the air. It is feared to cause global climate changes of irreversible and highly destructive type. Since the industrial revolution, the CO_2 content has risen by 25% and may double by the middle of the next century. For example, the atmosphere of the earth contains about 2000 billion tonnes of carbon as carbon dioxide. There is a consistent rise of CO_2 content from 315 ppm (0.0315%) in 1958 to 345 ppm (0.034%) in 1985 with a narrow seasonal oscillation every year (Hoffman & Wells, 1987). In nature, the rise of CO_2 is necessarily accompanied by a decrease in oxygen content which has harmful effects on living beings. Thus, the carbon-dioxide increase has manifold adverse effects, causing oxygen deficiency and green-house effect, on global weathers. The atmosphere has an estimated total carbon content of 17 x 109 tonnes calculated on the average concentration of 0.0335%. Roughly, the annual balanced exchange rate between the atmosphere and the terrestrial biosphere is 56 x 109 tonnes. Besides, an additional 5 x 109 tonnes are added every year through combustion of fossil fuel and this rate is increasing alarmingly. The National Academy of Sciences of USA and the U.S. Environmental Protection Agency (EPA) have made future projections of rise in carbon in the atmosphere; EPA estimates are more alarming.

<u>Oxides of sulphur</u>: It is the second most abundant contaminant, next only to CO, accounting for about 20% by weight of the entire air pollution. It is emitted into the atmosphere by some natural and mostly managed agencies. The principal man-made sources are

thermal power plants, metallurgical operations, oil refineries and the like which burn huge amount of fossil fuel. Coal and crude petroleum contain some quantity of sulphur which on burning, gets converted into SO_2 and reaches the atmosphere. In crude petroleum, the sulphur content may be from 0.1 to 0.5% in North Africa and 1.5 to 3% in the middle East. In coal mining areas of Jharia, India, one can see stacks of raw coal being partially combusted and thick cloud of dark yellowish grey fumes covering the ground surface. In metallurgical operations, like roasting of ores of Co, Ni, Zn and lead, huge quantity of SO_2 is emitted. The vegetation is totally destroyed around copper smelters. Sulphuric acid and paper industries also emit enough of SO_2. The SO_2 emission in the city of Calcutta is about 120 tonnes per day. Seasonal high SO_2 emission, is in winter when more warming is required and more coal is burnt or more electricity is generated. In heavy industries the smoke spreads to much wider areas. If the emission is near the ground surface as through burning of coal for cooking or small scale industries, the sulphur-rich smoke forms smog which is injurious to health and causes many diseases in humans and plants. One very important role of SO_2 pollution is its reaction with the atmospheric moisture and formation of sulphurous and sulphuric acids which come down with rain water. SO_2 pollution spreads up to several hundred kilometers from the source of emission. The pollution effects initiate at the molecular level by disruption of enzymes and cell membranes. Then the effect gets magnified in malformations reduced growth, sicky appearance etc.

finally causing the deaths of more sensitive species. The oxidising power of dissolved SO_2 badly affects the electron transport system. SO_2 mainly enters the plant leaf through stomata and to a lessor degree through the cuticle. SO_2 also competes with CO_2 and retards photosynthesis and carbon fixation. The combined effect of two or more pollutants is more severe.

Oxides of Nitrogen (NOX): In the atmosphere, NOX are present in traces and are formed during thunderstorms and stratospheric oxidation of ammonia. These are principally emitted by chimneys of factories due partly to coal or petroleum fuel and partly to oxidation of the atmospheric nitrogen under the high combustion temperature of factory furnaces. For each tonne of coal burnt, there is nearly 5-10 kg of NO_2 emission from diseal. For petroleum driven transport it may range from 25-30 kg per tonne of the fuel. The more a country is developed, the more it burns coal and the greater amount of NOX are emitted. The most serious polluting property of NOX is being a precursor of peroxyacytyl nitrate (PAN) and ozone which are highly toxic to plants. PAN enters leaves through stomata and reduces photosynthesis through injury to chloroplast, inhibition of electron transport and interference with enzyme systems connected with photosynthesis. PAN is a secondary pollutant forming smog by the action of light on hydrocarbons and nitrogen oxides in air. Smog is responsible for chronic diseases like bronchitis and asthama. It causes eye irritation and reduces visibility. It caused death of thousands in London in December, 1952.

Ozone: Ozone layer prevents the ultraviolet radiations to pass through and so the plants, animals and man escape the hazardous ultraviolet radiations that have damaging effects on cells and the genetic material. The total azone content of air is very little. It is present in traces; its content increases reaching the maximum level at about 25 km upwards. The main concern about depletion of the ozone layer is connected with the increased filteration of ultraviolet rays. UV- -radiation causes mutation in cells. Plants have been found to be adversely affected by UV- -radiations, cabbage, pea, cucurbits, soybean etc. being much sensitive. The damaging effect is through chloroplast, DNA and enzyme systems. In Antarctica zone, recently a rapid depletion of ozone "known as ozone hole" has been discovered. A rapid decrease in thickness of the ozone layer occurs in as studied through satellite observations October months in years 1979 to 1985. The decrease or hole formation begins in mid September, the peak depletion is reached in the middle of October and normalization completes by the end of November. Ozone is an important phytotoxicant that reaches plant crops through smog and causes injury to several species. Ozone enters through open stomata and effects plasmalemma causing leakage of cell contents into intercellular spaces. Persons having occupational exposure to ozone suffer from reduced eye sight, fatigue, headache, breathing problems and chest pains.

In addition to the man-made ozone sources like Chlorofluorocarbons ($CFCl_3$), fertilizers, biomass burning, aeroplanes and use of fossil fuel, there are natural sources like volcanoes, lightning and natural composition under anaerobic conditions. $CFCl_3$, the stable layer of the atmosphere, and come in contact with the ultraviolet radiations that break $CFCl_3$ releasing chlorine from it.

One atom of chlorine released by the action of UV radiation of $CFCl_3$ break two molecules of ozone into three of oxygen and again the same chlorine atoms acts a fresh on new ozone molecules. Chlorine thus acts as a catalyst and just one chlorine atom can destroy several thousands of ozone molecules before the released chlorine gets converted into dilute hydrochloric acid and comes down as acid rain. Similar catalytic action of breaking ozone into oxygen is also performed by bromine, NO, OH and H.

$$OH + O_3 \longrightarrow HO_2 + O_2$$
$$HO_2 + O \longrightarrow OH + O_2$$

Thus OH is completely regenerated to dissociate new ozone molecules. OH may be generated by oxidation of methane.

$$CH_4 + O \longrightarrow CH_3 + OH$$

The nitrogen system of ozone breakdown is very important. N_2O produced by biological denitrification very slowly reaches the stratosphere where it gets oxidised into NO

$$N_2O + O \longrightarrow 2NO$$

$$NO + O_3 \longrightarrow NO_2 + O_2$$

$$NO_2 + O \longrightarrow NO + O_2$$

Oxygen is formed and NO is regenerated until NO_2, an intermediatry compound, is eventually acted upon by water and acid precipitate in the form of rain. Thus, besides dissociating ozone, these three break-down systems, namely OH from water, NO from N_2O and Cl from $CFCl_3$, and up in precipitating HNO_3 and HCl.

In view of the global environmental problem that might arise due to depletion of ozone layer, there is a world-wide movement to prevent $CFCl_3$ emission in the atmosphere.

Acid Rain: The conversion of oxides (such as those of sulphur and nitrogen) in acid because of interactions in the atmosphere is commonly called acid rain. These acids are brought down to the earth with rains and bring about a change in the pH of the soil. There are a number of sources of acid rain. Ozone depletion in stratosphere over certain parts in USA is found to increase the level of smog leading to an increase in acid rain. Sulphur oxide in reaction with atmospheric moisture forms sulphurus and sulphuric acid which comes down with rain water. When the acid content becomes high and pH falls down to 5,4 or even upto 2-5, we call it "Acid rain" which damages the crops, forests, aquatic ecosystems, corrodes buildings, affects drinking water storage sources and upsets the biological processes in soil. In Europe and America, entire forests have suffered heavy tree mortality due to acid rain.

<u>The Green house effect</u>: This is the heating effect through re-radiation heat is trapped inside, thus increasing the inside temperature. Similar effect is caused in the atmosphere. Natural green house effect is necessary for the optimisation of temperature range for living things to exist on earth. If there is no blanket of infra red absorbing gases, the night temperature would fall much below the freezing point even in the warm tropics. But the hazardous aspect in the current green house effect is the increase of such gases in the atmosphere which would increase the present level of warmth to higher average temperature. The consequence of 1.5°C to 4.5°C rise from the present day average temperature would lead to

i) more evapotranspiration
ii) increase in rainfall
iii) the excessive melting of polar ice,

leading to rise in the ocean level by 20-140 cm. which will have a direct effect on coastal lands. During the past twenty thousand years the earth's temperature has risen by 4-5°C, but then the profound changes in forests, lakes, hydrology etc. did not affect man so much because his population was very little, his life style was simple, his needs were meagre. But in the present times when man is the most dominant and demanding component of the biosphere, he cannot afford to neglect the global climatic changes that are likely to cause major upheavals. Unlike other pollution problems, the green house warming effect cannot be reversed in a few years time by applying antipollution methods. The effect is long range lasting over to centuries. The change is slow and imperceptible but over several years its impact would become alarming and irreversible. We have no technology to destroy or reduce the accumulating green house gases. EPA (1987) documents expects that warming up would lead to significant changes in the forest species even though biomass may not be much affected in the North African forest. Green house gases would alter temperature regimes and therefore the hydrological cycles, and affect infiltration and storage in soil pool. Effects on crop production, with a rise of 1.5 - 4.5°C, will be manifold. Pest infestation may increase with rise of temperature. In regions where thermal regime is already towards the upper tolerance level, even a rise of 2°C may harm much. The US National Aeronautics and space administration (1986) have estimated that about 5% increase per year is taking place for green house gases in the atmosphere. Green house gases are going to affect human health through weather modification; several diseases like Malaria, Influenza, Bronchites and Pneumonia, break-out in certain localities in a particular weather condition.

<u>Hydrogen Fluoride</u>: Hydrogen fluoride is released in cumbustion process of fossil fuel and from aluminium industries and phosphate reduction plants. Gaseous fluoride enters plant body through stomata whereas particulate fluoride gets adsorbed, thereby reducing the transpiration. Fluorides possibly accumulate in the

chloroplast and damage the membranes. Necrosis, etching, chlorosis and discolouration are symptoms of fluoride injury. Fluorine possibly disrupts the calcium, magnesium and potassium balance, this adversely affecting the nucleic acid synthesis and functions. Conifers around the aluminium industries died in USA in the past, only by effective antipollution measures the vegetation could return to its normal. A great portion of fluoride occurs in the form of calcium fluoride or the mineral fluorspar (CaF_2) and the mineral cryolite; when used in industries, releases huge quantity of fluoride gas. This hampers respiratory processes and causes swelling of mitochondria and leakage of proteins.

R E V I E W

OF

L I T E R A T U R E

Air pollution is a major problem posed to the entire world today. Rapid urbanization and industrialization have made for a release of waste and harmful products into the atmosphere. Societies have been reluctant or have simply failed to recognise the limitations of the cleansing properties of the atmosphere. Air pollution has affected the health and well being of people, and caused wide spread damage to vegetation, crops, wildlife, buildings and climate.

No organism is independent of its environment. Every living thing, constantly influences and is, in turn, influenced by its organic and inorganic surroundings. Plants breath in air from the atmosphere and take up nutrients from the soild in the form of solution. The various gases and the inorganic substances present in air, water and soil are converted into complex organic molecules by green parts, mainly leaves, of plants in the presence of sunlight through different chemical processes. Excess of either essential or non-essential elements and presence of the gaseous pollutants into the air affect the performance of plant directly or indirectly by inhibiting or accelerating the plant metabolism, which may influence its productivity.

The awareness about pollution effects on vegetation has arisen during the current century and the effects of SO_2, fluoride, hydrogen chloride and other pollutants have been observed (Haselhaff & Lindau, 1903; Hedge Cock, 1912; NRC, 1939; Middleton et al., 1950; Adams et al., 1952; Thomas &

Hendricks, 1956; Middleton, 1961; Brandt & Heck, 1968; Heck, 1968a,b).

Pollution disturbs plant physiology. In case of Pinus nigra, air pollution causes early leaf fall (Gabor & Turesangi, 1987). There occur defoliation in Dactylis glomerata and Lolium perenne (Ashenden, 1987) and a significant loss in floral-bud production and fruit set in Abelmoschus esculentus (Gupta & Ghouse, 1986). There is an increase in leaf abscission in Glycine max (Norby et al., 1985). Any loss or accumulation of minerals cause disturbance in the physiology of plants. Decrease in the foliar mineral nutrients due to air pollution was noted in Glycine max (Norby et al., 1985). Under conditions of aerotechnogenic pollution, the accumulation of technogenic elements (Pb, Cd, Zn) in leaves was found to be related to increasing degree of aerotechnogenic heavy metals flow in Quercus mongolica (Arzhanova & Elapatevskii, 1988). Under the industrial omissions, seeds accumulated higher amounts of metals, such as Pb, Cd, Zn, Ca, Fe and Cu in Pinus sylvestris (Palowski & Bernard, 1986), whereas, iron, sulphur and phosphorus content and the caloric value reduced in maize. On the contrary, calcium content increased (Panday & Simbu, 1988). In Pinus sylvestris, germinability declines and accumulation of metals like Pb, Zn, Cd, Cu, Fe and Ca increases (Palowski, 1986). Inhibition of organic content of seeds was noted in Acacia auriculiformis, Cassia siamea, Ceiba pentadra, Delonix regia, Erythrina indica, Leucena leucocephala and Polyalthia longifolia (salgare & Anis, 1988).

Acidic rain of gaseous air pollutants cause marginal necrosis, leaf deformation and loss of photosynthetic area in Glycine max. (Norby & Luxmoore, 1983). The effect was very severe with small necrotic lesions on leaf surface in maryland tobacco, (Aycock, 1982) and Pisum sativum (Young & Mathews, 1981) Intraveinal foliar chlorosis and necrosis were reported in Ficus bengalensis (Gupta & Ghouse, 1987) and chlorotic mottle and tip necrosis in Pinus blanksiana and P. strobus (Armentano & Menges, 1987). Leaves first develop certain protective adaptations and ultimately fell prey to the harsh atmosphere. Stomata and trichomes usually undergo changes pertaining to size and frequency; their relative abundance mostly increases and the stomatal opening enlarges under polluted conditions (see Wangoner, 1975; Jafri et al., 1979; Zaidi et al., 1979; Yunus et al., 1979, 1982; Ghouse et al., 1980).

Disorganisation of cuticular stariation patterns and sometimes dissolution of the cell wall also occur (cf. Yunus et al., 1979, 1982). On the contrary, decreased stomatal frequency, (Sharma & Butler, 1973; Sharma, 1977; Ghouse and Khan 1978; Bhiravarmurty & Kumar, 1983), reduction in the size of stomatal pores (Garg & Varshney, 1980) and morphological anomaly of stomata and subsidiary cells (Rajachindambaram & Krishnamoorthy, 1980) are also on record. A reduction in frequency length, breadth and area of stomata, length and breadth ratio, and in stomatal index was noted in Aegerantum conyzoides, Amaranthus spinosus, Altermanthera sessilis, Blumea eriantha, Cassia tora, Euphorbia hirta, Eclipta erecta, Heliotropium indicum and Malacnia capitata (salgare & Acharekar, 1988). Stomatal frequency decreases whereas trichome frequency increases in Pueraria lobata (Sharma et al., 1980). In Brassica oleraeea, Chenopodium album, Cicer arietinum, Dolichos lablab, Lantana camara, Sonchus asperllis and Withania somnifera, the stomatal-pore size is reduced, while trichome length and trichome density increase under the polluted atmosphere (Garg & Varshney, 1981). There is a decrease in the stomatal frequency but an increase in trichome frequency in Pueraria lobata (Sharma et al., 1980). In Commelina bengalensis also, the size and number of stomata decrease whereas those of trichomes increase (Mishra, 1982). In Catharanthus roseus and Lantana camara, frequency length, breadth, area as well as index of stomata are reduced on both leaf surfaces (Salgare & Chakraborty, 1988). There is a decrease in the stomatal density but an increase in size and density of trichomes per unit of leaf area in Croton bouplandianus (Zaidi et al., 1979). Likewise, the stomatal frequency was reduced and the trichome frequency was increased in Callistemon citrinus (Ghouse et al., 1980). There is an inhibition of stomatal indices on either surface of the leaf of Alisicidia sepium, Ceiba pentandra, Delonix regia, Erythrina indica, Pentholobium dulces and Pongamia pinnata (Salgare & Anis, 1988). On the contrary, the density and size of trichomes increase with the degree of pollution in Croton bonplandianus (Amani et al., 1979). Similarly the frequency and size of stomatal pore and guard cells were noted to increase in

Atrocarpus integrifolia, Ficus bengalensis, Mangifera indica and Psidium guajava whereas Alistonia scholaris, Ficus religiosa, Mimosa elengi, Polyalthea longifolia and Syzygium jambos did not exhibit any reasonable change in the frequency or size of stomata (Debnath & Nayar, 1983).

Pollution also affect seed germination. Inhibition in the rate of germination and tube growth was reported in Catharanthus roseus (red flower) (Salgare & Sebastian, 1988), Allamanda catharlica and Cassia siamea (Salgare & Rane, 1988) and Gliricidia seprium (Salgare & Sebastian, 1988). Pollen germination and seed viability were reduced in certain weeds such as Cassia tora and Cassis occidentalis (Krishnayya & Bedi, 1986). Productivity, size, frequency and viability of pollen was noted to be inhibited in Hamelia patens (Salgare & Sebastion, 1988).

A decrease in chlorophyll was seen in Glycine max (Norby et al., 1985) due to cement dust pollution. The chlorophyll content in wheat (Singh & Rao, 1981), and the chlorophyll, RNA and protein contents in young clover of Betula pendula and Cernus sanguina (Braun et al., 1980) were decreased due to pollution. Most species show a decrease in the chlorophyll and protein contents and in enzyme activity (Rabe, 1981). The chlorophyll content, transpiration rate, protein content and nitrate reduetase activity in Cassia siamea and Melia azadiracta were found to decrease due to heavy fly ash and cement dust (Kumarvat & Dubey, 1988). The photosynthetic pigment was reduced also in maize and soybean (Mishra & Shukla, 1986), young spruce, plants, alfalfa and barley(Rabe & Kareeb, 1980), Posidonia oceanica (Augier & Maudinas, 1979). Triticum aestivum (Singh & Rao, 1980), Cicer arietenum, Dolichos lablab, Lens culenaris, Phaseolus aureus and Vigna sinensis (Varshney & Garg, 1980), Amaranthus spinosus, Altermanthera sessilis, Agernatum comyzoides, Blumea eriantha, Cassia tora, Euphorbia hirta, Eclipta erecta, Heliotropium indicum and Malchia capitata (Salgare & Acharkar, 1988), white barely (Bokra, 1986), Ficus bengalensis (Gupta & Ghouse, 1987), and in Butea monosperma, Ficus benagalensis and Mangifera indica (Reddy et al., 1988). In response to pollution, plant temperature and evapotranspiration increase in maize (Angela, 1986). The catalase activity and pigment content are decreased due to excessive transpiration. (Bokra, 1981). The stomatal conductance and transpiration also increase in Butea monosperma, Ficus bengalemsis and Mangifera indica (Reddy et al., 1988). On the other hand, the transpiration as well as choronhyll content decrease in wheat, (Singh & Rao, 1981) and spruce (Kammerbauer et al., 1987), due to cement dust pollution. A decrease in transpiration rate and in ascorbic acid, proteins and carbohydrate contents was reported for Phaseolus aureus (Prasad & Rao, 1981). CO_2 assimilation declined in 6 years old Norway Spruce (Kammerbauer et al., 1987) and catalase activity enhanced in Croton bonplandianum (Panda, 1989). Air pollution also causes reduction in stem length, leaf area, flower size and fruit size as in Commelina bengalensis (Mishra, 1982), in the aerial and subterranean plant biomass, leaf number and leaf area per plant and fruit setting as in Polygonum glabrum (Khan & Khair, 1984). On the contrary, certain species such as Cassia occidentalis (Amani et al., 1979) exhibit an overall increase in size and weight of plant, shoot, root, fruit and leaves. In case of Acalypha hispida, Ceretophyllum hortaengi, Malva viscus, Nerium indica, Pothea scandens, Quisquatis indica and Tabernae montana shoot length, number of flowers and leaves, petiole length, lamina length, length-width ratio, moisture content and also the dry-matter production undergo a decline in the polluted atmosphere (Salgare & Chakrabarthy, 1988). There is an appreciable growth improvement particularly with reference to shoot dry weight in Agrostis tenuis, Festuea rubra, Bromus mollis and Holcus lentus (Iqbal, 1984). Reduction in root and shoot length, and in number of leaves, nodules, flowers and pods due to petrocoke pollution was observed in Phaseolus aureus (Prasad & Rao 1981).

The coal-smoke pollution has shown damaging effects on shoot growth, shoot biomass and leaf development as in Anagallis arvensis and Melilotus indica (Ghouse & Khan, 1983; Ghouse & Saquib, 1986). There is a decrease in number of flowers and spikelets, and in the general yield of winter barely (Bokra, 1986). Reduction has been noted in overall plant growth (Pinus nigra: Gabor, 1987), total dry matter (Zea mays and Glycine max: Mishra & Shukla, 1986), general yield (Soybean and wheat: Miller, 1983; Singh & Rao, 1981; Leaf lettuce, green onion, turnip and Beat: McCool et al., 1987; Maize: Bokra 1981, Angela 1986; Dactylus glomerata and Lolium perenne: Ashenden 1987).

The Coal smoke pollution may also bring about loss to wood formation as in Dalbergia sissoo (Ghouse et al., 1984) and Tectona grandis (Ghouse et al., 1984). It severely impairs development of tissue system such as xylem, pith or cortical regions in Chenopodium album (Saquib et al., 1986). Bark tissues are also affected by the atmospheric pollution; ray frequency significantly declines while ray dimensions increase across in the bark of Mangifera indica (Kalimullah et al., 1987). The conducting region of phloem was reduced and the non-conducting phloem and periderms broadened in Mangifera indica (Ahmad et al., 1986). Reduction in cell size and proportion of different tissue systems was apparent in Calatropis gigentia (Iqbal et al., 1986), as also in length, width and average area of vessels in Polygonum glabrum (Khan et al., 1984). Reduced amount of cortex and secondary xylem and smaller size of vessel elements and fibres were noted in Chenopodium album (Ghouse et al., 1985). Also there was a decrease in the stem circumference in Cajanus cajan (Ghouse et al., 1989). A similar suppression of growth parameters, as described above was noticed in Datura inoxia (Iqbal et al., 1986). However, stem circumference increases in Cassia tora and Cassia oxidantalis (Iqbal et al., 1987) growing at the polluted sites.

Air pollution is due mainly to the combustion of fossil fuels, such as coal and petroleum etc. In power plants and many other industries coal has been the primary fuel for smelters for the last seven hundred years. The 70% of the total power used all over the world is generated by coal burning. Astanin and Blagosklonov, (1983) showed that most electric power plants which burn 2,000 tonnes of low grade coal a day emit about 400 tonnes ashes and 120 tonnes of sulphurous gas every day. Data show that in an 875 MW power plant, burning 1% sulphur fuel oil would emit about 55,000.000 pounds of SO_2 19 000.000 pound of NO_2 and 900,000 pounds of particulates per year; (Amani, 1982a). This may grow manifold unless an improved control technology is developed. The following review elucidates the sources and properties of different air pollutants, the mechanism and mode of their action and their effects on morphology, growth, biomass and productivity of plants.

Oxides of Carbon

Carbon monoxide gas (CO) is formed by incomplete combustion of fossile fuel like coal and petroleum or other organic matter. It is deleterious for the living beings, but it rarely approaches the nuisance threshold on a local or national basis. This gas accounts for about half the total air pollutant added to the atmosphere. There are reports that in U.S.A. alone, more than 65 million tonnes of CO is emitted annually in Calcutta city, the annual global input of this toxic gas being 6×10^{14} g or 6,000,000,000 tonnes.

CO is not toxic to plants as such, and vegetation is regarded as a natural sink for CO pollution. Bidwell and Fraser (1972) experimented with bean plants, using labelled carbon monoxide, to show that the gas is taken up by plants in considerable quantity. Inman and Ingersoll (1971), working with soils from California, Hawai and Florida, found that soil fungi in forest soils are very efficient in removing CO, while crop-field soils are not so efficient.

Carbon dioxide is a normal component of air and forms part of the carbon cycle in the biosphere. It is not considered as a pollutant in normal case. However, huge guantities of CO_2 emitted into the urban air every day due to the combustion of coal oil and gasoline turn out to be hazardous. June(1963) reported about the thermal environment and other catastropi effects caused by the carbon dioxide buildup in the earth atmosphere. Climate variations recorded between 1900-1940, showed a general warming of the northern hemisphere due to increased carbon-dioxide concentration. It is estimated that the doubling of carbon-dioxide concentration in the atmosphere leads to an average 2.5^{o}C rise of surface temperature resulting into cloudiness and precipitation which increase the sea-surface temperature, reduces the CO_2 uptake, and hence enhances warming. Increased amount of CO_2 leads to its greater absorption by oceans making them more acidic and consequently altering their biological productivity (Sundaram, 1970). The immediate effect of carbon dioxide build up is encountered in a number of atmospheric reactions and scavenging processes. Weathering of rocks brought about a slow absorption of carbon dioxide (Haegen-smit & Wayne, 1968) and much is stored in the lime stone and dolomites. Sundaram (1977) points out that less than half of carbon dioxide is taken up by oceans and biosphere. Robinson (1968) suggests that there has been a steady increase in the atmospheric carbon dioxide since around 1900. Prior to 1900, the CO_2 concentration was about 290 ppm. It underwent an increase of about 40 ppm (nearly 14 percent) till 1960. Similarly, Sundaram (1977) points out that the present atmospheric background concentration of CO_2 is 330 ppm by volume, which is higher by 10% over the quantities in many earlier millennia. A 14% rise was reported in Hawai and South pole between 1958 and 1974. With a 4% annual increase of fuel consumption, the atmospheric CO_2 will reach 400 ppm by the end of the century, suggests Sundaram (1977). An eight-fold increase is likely to occur in the next two hundred years as the carbon dioxide absorption by oceans is distributed by the ecological imbalance emanated from man's misuse of the global resources. The annual concentration of CO_2 released from the Kasimpur Thermal Power Station has been noted to range between 1.804 and 2.664 ppm per hour (Amani, 1982b).

High concentration of carbon dioxide is considered to be beneficial by several horticulturists; the carbon dioxide enrichment of enclosed crops increases yield (Govindjee 1982). However, it is regarded as pollutant by those concerned about the climatic implications of increased "Green house effects". While investigating the influence of the atmospheric carbon-dioxide concentration on yield and seed germination, it was found that seed yield, and seed number increased, although seed weight was reduced in case of Glycine max (Ackerson et al., 1984; Baker et al., 1989). Mottling, abscission and early senenscence coupled with a loss in chlorophyll (a & b) and carotenoid concentrations, appeared in Ponderosa pine (Pinus ponderosa) (Houpis et al. 1988). The CO_2 enrichment brings about variations in a number of physiological processes such as photosynthesis and respiration. Under normal conditions, 0.03% of carbon dioxide gas, present in the atmosphere many a times, may act as a limiting factor in the photosynthetic process. An increase in the amount of CO_2 (upto 1%) causes a rapid increase in photosynthesis (Kochhar, 1982) and beyond this point it slows down, retards the process or perhaps makes it constant. Increased yield of plants (Brown & Escombe, 1902; Pantanelli, 1903; Kreusler, 1985, 1987). Higher concentration of carbon dioxide accelerates the rate of apparent photosynthesis and the accumulation of soluble sugars and starch and lowers down the leaf conductance and the rate of senescence in Glycine max (Havelka et al., 1984). On the contrary, it may also decrease the photosynthetic rate (Peet, 1984) as was observed in bush been (Phaseolus vulgaris) (Ehret & Jolliffe 1985). Willims et al., (1986) observed a decrease in the photosynthetic capacity, stomatal conductance and nitrogen and phosphorus concentration in two deciduous trees, while net photosynthesis by flage leaf of spring wheat increases to almost double (Kendall et al. 1985). That the increased CO_2 concentration has a definite repressing affect on respiration, was demonstrated by Kidd (1915) in germinating white mustard seeds. Phaseolus vulgaris CV. pure gold showed a decrease in CO_2 exchange capacity, an increased respiration rate and a high starch content (Ehret & Jolliffee, 1985). In Commelina communis, higher concentration of CO_2 increases the stimulation of stomatal opening and diminish the internal ATP level, ATP/(ADP & AMP) ratio and respiration rate (Shaish et al. 1989). This also enhances starch accumulation and export and leaf sucrose concentration (Hubur et al. 1984). On the contrary, protein percentage in seed decline (Rogerers et al. 1984). Potvin and strain (1984) found an increase in the net assimilation rate in Echinochlo crusgalli and Elusine indica.

High concentration of CO_2 brought about an increase in root dry weight in _Echinochlo crusgalli_ and _Elusine indica_ (Potvin & Strain, 1984) and in the total dry weight of _Lycopersicum esculentum_ and six cultivars of _Lactuca sativa_ (Mortensen, 1985). In _Glycine max_, this increases the specific leaf weight (Sionit, 1983), the total dry weight (Allen et al., 1988; Clough & Peet 1981; Peet 1984) and pod weight (Sionit et al., 1987). The number of nodes in the main stem, lateral branches, and floral buds increased (Baker et al., 1989), and the floral and fruit development was enhanced. _Ochroma lagopus_ and _Pentacle Atra macnlob_ showed an increase in total biomass, leaf area specific leaf weight and non-photosynthetic tissue (Oberbaulr et al.,1985). However, the leaf dry weight was decreased in Alaska pea (_Pisum sativum_) (Paez et al., 1980). In _Glycine max_, Rogers et al., (1984) also noted an increase in dry weight, rate of branch-internode elongation, leaf initiation, leaf expansion, mean relative-growth rate and mean net-assimilation rate, but the area of leaf decreased. An increase in the length of main stem, branch length, number of branches, leaf area, total dry matter and specific leaf weight was noticed in sweet potato (_Ipomea batata_) (Bhattacharya et al., 1985). _Echinochlo crusgalli_ and _Ellusine indica_ showed early development of inflorescence (Potvin & Strain, 1984). Leaf area also increased in _Pulrasla lobta_ and _Louicera japonica_ (Sasck, 1986) and in _Phaseolus vulgaris_ (O'Leary & Knecht, 1981). There was an increase in number and diameter of tubers of sweet potato (Bhattacharya et al., 1985) and in dry matter production in seven crops of carrot and eleven crops of radish (Idso & Kimball,1989), under the influence of high CO_2 concentration.

Oxides of Sulphur:

Katz (1961) estimated SO_2 emission, on world-wide basis, to be about 11-12 million tonnes per day from a copper smelter and 3-5 million tonnes per day from lead and zinc smelters. Sulphur compounds are probably most widespread and most intensively studied pollutants present in the atmosphere in gaseous forms. Sulphur is mostly present in coal, oil and petroleum. The concentration of sulphur dioxide ranges from short term speaks of a few ppb near point sources to average concentration of 70 ppb in industrial areas, and a background of 100 ppb in many rural areas of Great Britain (Fowler & Cape, 1982). The mean annual concentrations may vary considerably in different cities generally ranging from 0.035 ppm to 0.070 ppm, the highest daily means being three to four folds higher (Jalees, 1983). The annual concentration of SO_2 released from the Kasimpur Thermal Power Station has been estimated to range from p.010 - 0.016 ppm / hr (Amani, 1982).

SO_2 causes a significant increase in germination percentage in Zea mays (Chand & Yadav, 1989), whereas it reduces germination of spores in Adiantum capillusveneris (Wada et al., 1987). Pollen grains of Cicer arietinum, Nasturium indicum, Petunia alba and Tradescantia axillaris at the time of pollen-tube growth are more sensitive than at the time of pollen germination (Varshney & Varshney, 1981). SO_2 affected the seed germination in Brassica juncea, Medicago sativa, Pennisetum typhoideum and Raphanus sativus. The growth of seedlings especially of shoot was adversely affected (Banerjee & Chaphekar, 1980). A higher cumulative SO_2 dosage immediately caused an appreciable reduction in the plant growth and ultimately in the production level of plants (Singh & Rao 1986). Growth of shoots and roots of five woodly plant species was noted to be adversely affected (Norby & Kozlowski, 1981). Nicotiana tobacum, Cultivar samsum and Cucumis sativa cultivar unikat had a significantly reduced fresh weight of green leaves, shoots and roots (Mejstrik, 1980). Marchwinska and Kucharski (1987) concluded that a long term exposure to low levels of SO_2, even without visible plant injuries, resulted in more significant crop losses than to short term exposure to higher concentrations. Singh et al. (1983) found a marked growth reduction in alfalfa (Medicago sativa). Satyanarayan et al. (1985) reported that SO_2 affected pigeon pea (Cajannus cajan) root growth and nudulation, and decreased dry matter accumulation in all parts of seedlings. Prolonged exposure of rye grass (Lollium perenea) to SO_2 retarded the plant growth significantly. Agarwal et al. (1985) observed reduction in length of root and shoot, number of leaves, nodules and pods of Vicia faba. Tomer et al. (1987) showed reduction in all growth parameters at higher cumulative dosage in case of Raphanus sativus Cv. Japanese white. Reduced growth was noted also in hybrid poplar clone NE-388 (Populus maximomizie x P. trichocarpa Torr & Gray (Biggs & Davis, 1982) and Vigna mungo (Lalman, 1988). Pine stands were shown to be slightly injured with the annual shoot increment and the total above ground biomass reduced (Fedotov et al. 1983). The male reproductive organs are relatively more sensitive to SO_2.

Tsukahara et al. (1987) observed Betula platyphylla seedlings to be very sensitive to SO_2 as determined by leaf injury. Betula papyrifera (paper birch) and B. nigra (river hirch) showed injury to leaves and reduction in the mean relative growth rates (Norby & Kozolowski, 1983). At higher concentrations of SO_2 there was some visible injury of leaves, and leaf area was reduced in rye grass (Lolium perenne cultivar S_{23}) (Cowling, 1978). Chand & Kumar (1987) reported 0.25 & 0.5 ppm SO_2 causing visible foliar injury in the form of interveinal chlorosis and necrotic patches. Reynolds et al. (1987) studying field-grown red kidney beans (Phaseolus vulgaris) reported that increasing cumulative SO_2 concentrations resulted in a significant decrease in the rate of lesion apperance. Four agriculturally important grasses (Lollium perenne, Lollium multiflorus, Dactylis glomerata and Phleum parateus, showed chlorotic lesions after exposure to the highest concentration (Lockyer, 1985). Wilson and Bell (1986) studied the tolerance of SO_2 in Festula rubra and Dactylus glomerata populations and found a high degree of leaf damage after fumigation with a high conc. of SO_2. Kumar and Singh (1966) reported bifacial necrotic lesion on the middle and lower leaves in Pusa Barsati. Thompson (1985) showed chlorotic injury on wheat leaves and increased total leaf sulphur. Acute doses of SO_2 increased the stomatal resistance to acute injury but not in sensitive species (Ayazloo et al., 1982). Singh and Rao (1988) reported that in case of Vigna radiata the foliar injury is directly proportional to the concentration of SO_2. Winter barley

(*Hordeum barley* var. Jgri) showed leaf scorching (Bakar & Fullwood, 1986). Hasebe et al. (1986) showed in case of five fruit trees, viz., Pear, Peech, grape, apple and chestnut, acute specks of foliar necrosis (David et al. 1987). The degree of injury increased and plasmolysis occurred in the spongy and epidermal cells leading to shrinkage and tissue destruction (Kim, 1981). Plants of *Arachis hypogea* (ground nut) show necrotic lesions and a reduced net primary productivity (Mishra 1980). Visible foliar injury has been observed in forty six varieties of crops (Ichikawa et al. 1980), *Opuntia basilaris* (David et al. 1987) Spruce needles (Piene & Querlroz, 0, 1988) and *Zea mays* (Nyomaskay et al. 1986). In many plants, reduction in chlorophyll a and b has been observed, eg. in *Syzygium cumuni* (Jamun) (Vijayan & Bedi, 1988), *Raphanus sativus* (Tomer et al. 1987) and white bean (Beckerson & Hofstra, 1979). Soybean showed greater response to SO_2 than wheat with lower leaf extract pH, higher accumulation of sulphur on SO_2 treatment, and lower content of chlorophyll, ascorbic acid and total carbohydrate. It was concluded that leguminous crops were more sensitive to SO_2 than cereal crops (Prasad & Rao, 1982). In case of *Triticum aestivum* cultivar RR21 plant, carbohydrate contents, caloric values, phytomass accumulations and net primary productivity were increased initially after exposure to SO_2 but later decreased in all parameters (Prasad & Rao, 1981). Photosynthetic and respiratory activity were badly affected in *Phaseolus vulgaris* L. (Koziol & Jordan 1979), *Marchantia polymorpha* and *M. tinctorium* (Takaoki et al. 1986). In all tissue samples, levels of total sugars were increased by exoosure to the lower concentrations of SO_2, but decreased by the higher concentrations. Starch levels in leaves followed a similar trend in case of Lolium perenae (Cowling, 1978). Protein content increased when the concentration of SO_2 was low, but the higher levels had a toxic effects on protein in Soybean (Glycine max) and pea (Pisum sativum)(Sardi, 1981). The fumigation of SO_2 causes depression of transpiration and photosynthesis (Lore & Andreas, 1987). Significant effects of SO_2 were also found on the transpiration coefficient measured for Dactylis glomerata and Phleum pratense (Lockyev, 1985). Singh et al. (1985) showed the response of pre-flowering, flowering and post-flowering stages; photosynthetic pigments were degraded and leaf extract pH and protein content declined in SO_2 treated plants. Schmidt et al. (1988) suggested that stomatal acidification upon SO_2 uptake interferes with light activation of Calvin cycle enzymes. It also damages the photosystem II. Whereas Nandi et al. (1986) showed a reduction in the concentration of photosynthetic pigments and the starch in Oryze sativa. Griffith and Campbell (1987) showed that SO_2 may influence the carbon metabolism and transport in snapbean. Photosynthesis is inhibited by SO_2 fumigation in Marchantia polymorpha and M. tinctorium (Takaoki et al., 1986). Rye grass (Lolium perenne S23) is most sensitive to SO_2. SO_2 inhibits photosynthesis in field bean (Vicia faba Cv. 'three fold white and blaze) and in barley (Hordem vulgare Cv. 'Sonja' (Darrall, 1986). Lin et al. (1984) observed the breakdown of chloroplast in many crop plants. Chung (1982) showed an appreciable effect of pH change on leaf in barley with a reduction in absorption spectra of pigments. The chlorophyll content of leaf is reduced and the stomata of leaves can not shut during the night leading to excessive transpiration (Borka et al. 1981). Sprugel et al. (1980) showed decrease in the yield of soybean. Increasing cumulative SO_2 conc. entrations result in the reduction in yield in red kidney bean (<u>Phaseolus vulgaris</u>), (Reynolds et al. 1987). Catanescu et al. (1987) showed that wheat, rye, barley, peas and grapevine had a major yield reduction due to accumulation of SO_2. Effect of increasing doses of SO_2 reduced fruit yield by 18% and significant reduction in fruit number were also observed. The dry matter production and net primary productivity of <u>Solanum tuberosum</u> decreased (Kumar & Yadav 1986).

Oxides of Nitrogen:

Nitrogen oxides released in the atmosphere by coal burning are harmful to plants. The threat of these pollutants has assumed alarming dimensions today, because not only coal burning but any combustion process which creates high temperature in the presence of atmospheric nitrogen and oxygen, yields oxides of nitrogen (NO and NO_2) as combustion products (Wellburn et al. 1976; Ashenden, 1979; Law and Manifield, 1982). The hotter the flame, the greater the production of these oxides. The combustion dilutes gases present in the immediate atmosphere and part of NO, perhaps as much as 10% (1% of the total NO_X formed), is oxidized to NO_2. Once NO has been diluted to about 1 ppm of the air, it no longer reacts readily with oxygen to produce NO_2 (Taylor et al. 1975). NO_2 in presence of the radiant energy breaks into NO and atomic oxygen, which again combines with the moleculer oxygen of the atmosphere and forms ozone (Cox et al. 1975).

$$NO_2 \xrightarrow{hv} NO + O$$
$$O + O_2 \xrightarrow{m} O_3$$

hv = light energy

m = any inert molecule.

The net reaction can be summarised below:

$$NO_2 + O_2 \longrightarrow NO + O_3$$

Backward reaction is faster than forward reaction and hence Ozone gets removed from the atmosphere. Urban atmosphere possesses hydrocarbons, reacts with NO, and stops the backward reaction resulting into accumulation of ozone. NO_2 is the major constituent of vehicle exhaust gases; over 70% of the NO_2 in the atmosphere comes from the automobile exhaust (Treshow, 1970). It is believed that about 95% of NO_X is released as NO and the remaining 5% as NO_2 (Kumar, 1977). Robinson and Robins (1970) reported that NO and NO_2, produced naturally by bacteria and artificially by man made sources, constitutes about 50×10^7 and 5×10^7 tonnes of NO and NO_2 per year, respectively. Fowler and Cape (1982) reported that the annual emission of NO_X in North American and West Europe collectively amounts to about 80×10^6 tonnes per year, whereas the concentration of NO_2 in agricultural areas of the U.S.A. alone is 15×10^6 tonnes per year. The term NO_X is often used collectively to describe nitrogen oxides mixture, but in practice NO_2 alone has been preferred to study the phototoxicity of these oxides (Bennett & Hill, 1973). NO_2 is more harmful than NO and the uptake of NO_2 per unit area of leaf is almost three times that of NO (Capron & Mansfield, 1976, 1977). The concentration of NO_2 is much higher in smoggy days and sometimes exceeds the alert level of 3.0 ppm (Bush et al. 1962). The highest levels occurred at night; day time concentrations were reduced by participation of nitrogen oxides in photochemical reaction. Unsworth (1981) reported the daily mean concentrations of NO and NO_2 in rural conditions as 2 and 1-4 ppb respectively and in urban industrial conditions as 10-50 ppb for both the pollutants. The annual concentration of NO_2 released from the Kasimpur Thermal Power Station at Aligarh, ranges from 0.177-0.294 ppm per hour (Amani 1982).

NO_2 causes changes in dry weight of plants; leaf weight and leaf area ratio increases in maize and sunflower (Okano & Totsuka, 1985). Reduction in number, weight and dry matter percentage, and an increase in the rate of leaf abscission were noted in potato (Solanum tuberosum)(Sinn & Pell, 1984). Growth was suppressed in wheat and the net assimilation rate in Zea mays and Helianthus annus was reduced (Okano & Totsuka 1985). The former authors, however, showed an increase of protein content in wheat. Murray and Wellburn (1985) showed an increase in nitrate reductase activity in presence of NO_2 in tomato cultivars, whereas the activity was inhibited in Hordeum vulgare shoots (Rowland et al. 1989). There was an increase in nitrate content, the metabolic activity of nitrate assimilating enzyme and glutamic synthetase in shoot but a decline of nitrate reductase activity in root of spruce seedings (Tischner et al. 1989). Reduction in photosynthesis and transpiration was noted in Picea abies (Sex & Murali 1989).

Hydrogen Fluoride:

Exposure to hydrogen fluoride increased stomatal conductance in leaves of Eucalyptus (Murray & Wilson, 1988), whereas 4 rice varieties showed destruction of leaves and a decrease in yield (Cho et al. 1985). The Sorghum vulgare leaves developed chlorosis and necrosis; it was also with Tulipa gesneriana (Ibana et al. 1989). Reduction in surface area and weight of mature and immature leaves was also observed (Murray & Wilson, 1988). Yields decreased in wheat (MacLean & Schncider, 1981), and growth reduced (Hitchcock et al. 1964). Bunch weight, number of branches and yield in wheat were significantly affected (Murray, 1985), an effect on the xylem and phloem changed the colour red brown (Qin et al. 1980).

Hydrogen Sulphide:

There is a reduction in relative growth rate, and in the shoot - root ratio in spinach (Mass et al. 1987). The same plant showed a decline in CO_2 fixation and efficiency of phytochemical energy in photosynthesis (Mass et al. 1988). Dekok et al. (1986) showed inhibition of NADH oxidizing enzyme which resulted in increase in NADH supply to nitrate reductase in the presence of oxygen.

PARTICULATE AIR POLLUTION

The particulate materials present in the air have diverse effects, some are pathogenic too. There are several very minute particles that keep floating in the air. The particulate materials alter the heat balance of the atmosphere at local and regional levels. They affect visibility. In Delhi, at heavy traffic points in the winter afternoons and evenings, the atmosphere becomes hazy which not only reduces the visibility but causes burning of eye and initiate coughing. Industrial, mining and metallurgical operations produce lots of metallic dusts of copper, iron, zinc, steel, lead and aluminium. Among non-metallic industrially produced dusts are of cement glass, ceramics, asbestos etc. These particles reach the air during blasting, loading and unloading, drilling, crushing, grinding and drying of slury etc. From the toxicity view point, among the metallic pollutants, mercury is most toxic followed by lead, copper, cadmium, nickel and zinc. Lead is poisonous to man and does widespread damage to road-side vegetation. Lead inhibits electron transport in photosynthesis and cadmium affects the membrane of mitochndria and may affect nitrogenase activity and nodulation. Cadmium aerosol settle with rain on plants and through food chain reach animal and man. It causes several problems in plants such as chlorosis, foliar injury and root injury. In man, cardiovascular problems and hypertension are caused. Arsenic contamination from lead smelters causes death of fine roots, stunting of growth in plants and reduced mycorrhizal development. Aluminium toxicity causes chlorosis of leaf margin and defoliation. Asbestos is carcinogenic of proven fatality. Asbestos dust enters the nose and reaches the lungs, causes asbestosis cancer of lung and, thus thousands of workers employed in asbestos industry have died of the occupational hazards. Environmentalists hold that the asbestos manufacture should be banned outright. Cement dust around cement factories is very common. It is an oxide of calcium and silica which, when wetted, forms hard calcium silicate. Aluminium and potassium are also present. Very fine dust of cement falls on leaf surfaces and forms a thin but hard crust as it comes in contact with transpiring moisture. The crust seals the stomatal surface and materially affects gas exchange. Lal and Ambasht (1980) reported that the plant leaves receive cement dust at the average rate of 1.24 g/m^2 per day near the Churk Cement Factory.

Three power plants of Delhi (Rajghat, Badarpur and Indraprastha) use about 2,000 - 2,500 tonnes of coal and release about 600 tonnes of fly ash daily. Puri and Katyal (1984) reported that each tonne of the coal ash contains seventy elements including 700 gm nickle, 500 gm germanium, 400 gm uranium, 300 g cobalt, 200 gm tin, 100 gm lead, 20 gm bismith and 5 gm cadmium. The annual combustion of 180 million tonnes of coal in Great Britain, 0.6 million tonnes of asch, 24 million tonnes of smoke and 5.2 million tonnes of sulphur dioxide per year are released into the air (Meetham, 1952).

In New York, Katz (1956) estimated a dust-fall of 67.5, 61.2 and 33.3 tonnes/mile^2/month. A large amount of dust is emitted into the atmosphere by various thermal electric plants and combustion processes using low-grade coals. Astanin and Blagosklonov (1983) reported that most electric-power plants which burn 2,000 tonnes of low-grade coal a day emit about 400 tonnes of ashes and 120 tonnes of sulphurous gas energy per day. Several estimates by the "Bureau of Mines" suggest that the fly ash released into the atmosphere is about 10% of the total ash in coal, and the solid waste produced in the form of ash, after combustion of coal, is about 25 to 30%. This shows that with the present rate of coal consumption in thermal power stations, we are adding an estimated 12.21 million tonnes of fly ash into the atmosphere, of which nearly one third goes into the air, the rest getting dumped on land or in water (Fulekar et al. 1982). The dust particles present in the atmosphere differ in dimensions. The larger particles come down to the earth by gravitational pull, while the smaller ones float in the air and with the help of high wind cover great distances (Haegensmit & Wayne, 1968).

Acid rain effect on plant:

Acidic fog induces foliar injury to *Fragaria ananassa* (Takemoto et al. 1989). Foliar injury by acidic fog has been observed in *Allium cepa*, *Citrus sinensis*, *Lycopersium esculentum*, *Medicago sativa*, *Phaseolus vulgaris*, *Raphanus sativus* and *Spinacea oleracea* (Musselman & Sterrett, 1988), and Foliar necrosis in *Pinus jeffrey* and *Sequoia gigantia* (Temple, 1988). Old needles of *Picea abies* showed a weak chlorosis and damage of wax layer (Mengel et al. 1987). Acid rain caused foliar injury in *Beta vulgaris* (Evans et al. 1982). It reduced foliar pigment concentration (Takemoto et al. 1988). Foliar injury leads to retardation of photosynthesis (Takemoto et al. 1989). The acidic fog leached significantly higher amounts of K, Ca, Mg, Mn & Zn in *Picea ablis* with carbohydrate (Mengel et al. 1987) and reduced the stomatal conductance and photosynthesis in field gram and alfalfa (Temple et al. 1987). There is a linear decrease in the stomatal conductance in yellow poplar (Chapelka et al. 1988). Takemoto et al. (1987) observed no effects on *Glycine max* by acid rain; it did not affect photosynthesis, transpiration, stomatal conductance of water vapour or chlorophyll content. However, a decrease in protein content of seeds was observed (Evans et al. 1984). Battey (1988) showed that acid precipitation (of pH 2.5 or less) induced inhibition in photosynthesis and photorespiration in *Phaseolus vulgaris* seedlings. Acid fog reduced total dry yield in field gram (<u>Medicago sativa</u> L.)(Takemato et al. 1988) while in <u>Glycine max</u> it had no effect (Norby et al. 1985). Reduction in yield was observed in field corn (Banwart et al. 1988), field gram, alfalfa (Temple et al. 1987), pintobean (Evans, 1980), <u>Beta vulgaris</u> (Evans et al. 1982) and <u>Brassica oleracea</u> (Takemoto et al. 1989).

POLLUTANTS INTERACTION

The plant growth, morphology, physiology or biochemistry is hindered by the presence of various pollutants and their combinants, such as O_3, NO_2, leading to the damage of plant. SO_2 in combination with O_3 showed reduction in stomatal conductance to water in Garden pea (Pisum sativum)(Olszyk & Tingey, 1986). On the contrary, the stomatal conductance is enhanced in barley (Hordeum vulgare)(Ashmore & Onal, 1984). Reduction in growth also appeared in barely (Ashmore & Onal, 1984) and Soybean (Reinert & Weber, 1980). A marked inhibition occurred in the vegetative growth of Glycine max Cv. Davis (Norby et al. 1985) as also in the total nodule activity (Jones et al. 1985). The yield showed no reduction in Oryza sativa, M 7, M 9 and S_{201} (Kats et al. 1985). Tuber number and total tuber yield in potato (Solanum tuberosum, Cultivar Centennial Russet) was reduced (Foster et al. 1983). Reduction in ear and grain show quantitative and qualitative deterioration in common millet, (Panicum miliaceum) (Agarwal et al. 1983). Heggestard et al. (1986) showed reduction in fruit yield and fruit number though fruit quality was unaltered in Tomato (Lycopersicum esculentum). There is an increase in the stomatal resistance of both upper and lower primary leaf surfaces in white bean (Phaseolus vulgaris)(Beckerson & Hofstra, 1979). Pratt et al. (1984) showed visible injury in Soybean, while Heagle and Johnssen (1978) reported foliar injury and alteration in shoot and fresh weight. In case of rice, foliar injury of different levels was reported (Agarwal et al. 1982). Whereas interveinal chlorosis and premature leaf drop was reported in white bean (Phaseolus vulgaris)(Beckerson & Hofstra, 1979). Pinto bean (Phaseolus vulgaris cultivare Pinto 111) showed abaxial glazing or silvering and induction of greatest macroscopic foliar injury (Miller & Davis, 1981) Chlorotic mottle, tip necrosis and needle retension were noted in Jack pine (Pinus blanksiana) and white pine (P. atrobus)(Armenato et al. 1987), the latter also showed tip burn and mottling (Rezabek et al. 1989). Reduction in root, shoot length and biomass was also reported (Agarwal, 1983; Keith, 1981). The biomass was reduced in radish (Raphanus sativus)(Chris & Williame, 1989). In potato, there was a reduction in leaf dry weight (Foster et al. 1983). There was likewise, a significant reduction in height growth and dry matter production but an increase in leaf area ratio in yellow poplar (Liriodendron tulipifora)(Chappelka et al. 1985). On the other hand, there is an increase in leaf and stem dry weight in Glycine max Cv. Maple arrow and is Lycopersicum esculentum Cv. New York (Deveau et al. 1987). There is no reduction in dry weight or surface area in pea (Pisum sativum cultivar. a/s weat)(Olszyk & Tibbitts, 1982). SO_2 in combination with O_3 caused decline in chlorophyll a and b in white bean (Phaseolus vulgaris cultivar sanitav)(Beckerson & Hofstra, 1979) and in Oryza sativa (Agarwal et al., 1982). In Glycine max a reduction in membrane permeability (Beckerson & Hofstra, 1980) and CO_2 rate (Lesuer & Ormrod, 1984) was noticed. Reduction in foliar concentration of mineral nutrients and the nitrogen fixation capacity but an increase in leaf abscission were noted in Soybean (Glycine max)(Norby et al. 1985). A reduction in foliar chlorophyll concentration but an increase in the foliar sulphur concentration have been found (Pratt et al. 1983; Jones et al. 1985) in many plants including pea plants (Olszyk & Tibbittis, 1982). Black et al. (1982) showed a decrease in photosynthetic rate in Vicia faba, whereas Satoh et al. (1987) reported reduction in the protein content and premature senescence in lower leaves in bean (Phaseolus vulgaris).

SO_2 in combination with NO_2 brought about premature senescence of leaves in Glycine max. (Irving & Miller, 1984). It caused growth inhibition and foliar senescene and abscision in six broad-leaved trees (Freer & Smith, 1984); leaf injury occurred also in six cultivar of Raphanus sativus (Godzik et al. 1985). It caused visible injury with a reduction in dry weight in Cicer arietinum Cv. C-235 (Kumar & Singh, 1985) and Betula pendula (Smith, 1985). Light brown patches along the margin and wax accumulation in small leafs also appeared (Pande & Oates, 1986). The palisade cells become flaccid and spongy and the tissue is completely collapsed in Commelina communis (Gould & Mansfield 1989). Necrosis and a reduction in yield of wheat (Irving & Miller 1984; Kumar & Singh, 1985; Kumar Naresh 1986, Ashenden & Williams 1980) are commonly observed. All the parameters related to growth had a decline in spring barley (Hordeum vulgare Cv. Patty)(Pande & Mansfield, 1985). The leaf-water concentration decreased in Lycopercium esculentum (Marie & Ormrod, 1984). There is an increase in the premature leaf loss together with a reduction in weight (Wright,1987) and root fresh and dry weight (Petter & Ormrod, 1988). Strong leaf fall and significant loss of leaf area (but with increase in production of leaves) was noted in Pisum sativum (Edelbauer & Maier, 1988). Growth of plant is also effected in Sorghum bicolor (Pandey, 1984). The SO_2 in combination with NO_2 increased the rate of transpiration to almost double in birch (Betula spp.)(Neighbour et al., 1988), while it brought about a decrease in Phaseolus vulgaris (Ashenden, 1979). An inhibition in photosynthesis and transpiration was also apparent in Norway spruce (Picea abies: Saxe, 1989). Chlorophyll a and b and the total chlorophyll content of leaves in Vigna radiata (Cultivar ML-5) decreased (Kumar, 1986): the chlorophyll was degraded in Glycine max (Irving & Miller, 1984). Wellburn et al. (1981) showed reduction in cyclic photophosphorylation, ATP content and energy change ratio, while there was no change in Glutamate dehydrogenase activity, Glutamine synthetase ratios and basic electron transport system in three clones of Lollium perenne with the grasses (Dactyles glomerata, Phlem partens & Poa partensis).

Combination of SO_2 and HF brought about a reduction in surface area and weight of mature leaves of Eucalyptus (Murray & Wilson, 1988). A decrease in the number of seeds per conc and in dimensions and weight of cones, an increase in the abortion rate of cones, and a delay in lignification have been noted in Pinus sylvestris (Roques et al. 1980). Foliage reduction was noted in Zea mays (Mandl et al. 1980). This combination caused foliar injury in conifers (MacLean et al. 1986). Mandle et al. (1980) showed chlorotic lesions and a reduction in yield, and in fresh and dry weights of sweet corn stalks. Sugar content reduces in the needle of Scotch pine (Mejnartowicz & Lukasiak, 1986), whereas concentration of grain protein increases in barley and wheat (Murray & Wilson, 1988). It also increases leaf fluoride concentration (Murray et al. 1981), sulphydryl compounds and sulphate in spinach(Mass et al. 1987). Very high amounts of total sulphur and soluble fluoride accumulate in leaves of selected free species (Chmidewski et al. 1986), though there is a decrease in the overall yield (Mass et al. 1987; Sharma and Rao 1984; Buckenhem et al. 1983).

Cement and NO_2 in combination brought about reduction in chlorophyll content and biomass accumulation in Triticum aestivum (Singh 1980) and a quantitative and qualitative deterioration in grains. Ozone in combination with NO_2 increased the total nitrogen content but decreased the assimilation of NO_2 and concentration of soluble sugars (Osamuito et al. 1985). Ito et al. (1986) showed an increase in the ammonium level and percentage of aspargine in kidney bean (Phaseolus vulgaris). Reduction in growth rate and assimilation rate in yellow poplar (Liriodendron lutipefera) (Jensen, 1985) and in leaf and stem fresh weight and leaf area in tomato (Goodyear & Ormrod, 1988) is also on record.

P L A N

OF

W O R K

PLAN OF WORK

To study the impact of coal smoke pollution on growth and morphology of certain annuals, the following plan of work will be adopted:

Sélection of the site

The present study will be carried under the field conditions for three consecutive years at Aligarh and Kasimpur, considering the former as control and the latter as polluted sites.

Control site at Aligarh

The control site of study will be selected at the experimental station situated about two kilometers away from the campus of A.M.U., Aligarh in a rural area which is almost free from pollutants, even from vehicular traffic and domestic fuel burning.

Polluted site at Kasimpur

Kasimpur, in the district Aligarh, is situated in the North-East of Aligarh City at a distance of about 16 kilometers. Here a Thermal Power Complex (one of the three major power stations in Uttar Pradesh) came up some forty years back on the bank of an irrigation canal which runs in east-west direction.

The power complex includes three power houses namely, 'A', 'B' and 'C' (C_1 and C_2) having a capacity of 90 MW, 210 MW and 230 MW, respectively. The total consumption of coal per year on an average comes to about 1165077 metric tonnes. The coal so consumed is of Bituminous type and on combustion produces CO_2, SO_2 and NO_2, respectively. Out of these sulphur dioxide is the main pollutant and it is believed that coal burning is responsible for about 60% of SO_2 pollution around sites (Rohrman and Ludwig, 1965).

The coal, being used in the power plants, will be analysed chemically. The amounts of CO_2, SO_2 and NO_2 being released due to burning of coal and added to the biosphere in Kg per hour and part per million (ppm) per hour will be worked out.

Selection of the Experimental Weed Species

To conduct the present investigation, a general survey of both, the control and polluted sites, is made and a list of common weed species growing, is prepared season and family-wise as follows:

Rainy Season

Families	Weed species
Acanthaceae	*Justicia simplex* - D. Don *Peristrophe bicalyculata* - Nees *Rungia pectinata* - Nees

Families	Weed species
Amarantaceae	Achyranthes aspera - Linn. Alternanthera sassilis - R. Br. A. pungens - H.B. & K.
Asclepiadaceae	Calotropis procera - Dryand
Compositae	Xanthium strumarium - Linn.
Labiatae	Ocimum sanetum - Linn.
Leguminosae (Papilionatae)	Cassia occidentalis - Linn. C. sophera - Linn. C. tora - Linn. Indigofera anabaptista - Stend.
Lythraceae	Ammania baccifera - Linn.
Onagraceae	Ludwigia parviflora - Roxb.
Solanaceae	Physalis minima - Linn. Withania somnifera - Dun.
Tiliaceae	Corchoris acutangulus - Lam. C. romboidae
Winter Season	
Caryophyllaceae	Silene conoidea - Linn. Spergula arvensis - Linn. Stellaria media - Cyrill.
Chenopodiaceae	Chenopodium album - Linn. C. ambros - Linn. C. murale - Linn.
Compositae	Gnaphalium indicum - Linn.

Families	Weed species
Cruciferae	<u>Coronopus didyma</u> - Sm.
Euphorbiaceae	<u>Croton bonplandianus</u> - Baill. <u>Euphorbia dracuncoloides</u> - Lam.
Leguminosae (Papilionatae)	<u>Lathyrus aphaca</u> - Linn. <u>L. sativus</u> - Linn. <u>Melilotus indica</u> - Derr.
Liliaceae	<u>Asphodelus tenuifolius</u> - Cav.
Papaveraceae	<u>Argemone mexicana</u> - Linn. <u>Fumaria indica</u> - Pugsley
Primulaceae	<u>Anagallis arvensis</u> - Linn.
Scrophulariaceae	<u>Veronica anagalis</u> - Linn. <u>V. agrestis</u> - Linn.
Solanaceae	<u>Solanum xanthocarpum</u> - Schrad and Wendl (<u>Surattens</u>) - Burm.

Out of the above prepared list, 3 weed species will be selected in each season at flowering and post-flowering stages for their morphological, anatomical and biochemical responses to coal smoke pollution. The effect will be determined by applying the following methods.

Morphological studies

1. Plant height
2. Root length

3. Shoot length
4. Root biomass
5. Stem biomass
6. Leaf biomass
7. Leaves per plant
8. Leaf area per plant
9. Average single leaf area
10. Flower per plant
11. Seeds, pods and capsule per plant.

The plant height, root and shoot length will be measured in cm. The shoot length will cover the plant axis from the ground level to the upper most growing tip of the main axis, while for root length the main tap root will be measured from the ground to the root tip. The plant height will indicate the length of the entire axis extending from root tip to shoot tip.

To find out the biomass of a plant species, root, shoot and leaves of the samples will be over dried separately at 80°C for 48 hrs and its dry weight in gram will be determined on a chemical balance.

The number of fully opened leaves will be recorded on each individual of the selected weeds. Out lines of randomly selected ten leaves will be drawn on a tracing paper, and the area occupied by the drawing will be measured with the help of a planimeter. For very small leaves area calculated will be measured on graph paper. The average area of a single leaf will be multiplied by the total number of leaves per plant to obtain the total green leaf area in cm^2 per plant.

Flowers, seeds, pods and capsules per plant will be counted on their appearence at flowering and post-flowering phases on randomly selected individuals of each species.

Anatomical studies

A. Epidermal Features:-

1. Stomatal frequency
2. Dimensions of stomata
3. Size of stomatal pore
4. Stomatal index
5. Epidermal cell frequency
6. Trichome length
7. Trichome frequency

B. Root and Shoot Anatomy:-

1. Fibre length in stem and root
2. Vessel element size in stem and root
3. Frequency of vessel elements in root and stem
4. Root and stem circumference
5. Root and stem area
6. Cortex area in shoot and stem
7. Vascular area in root and stem
8. Pith area in root and stem.

A.

Epidermal peels will be obtained with the help of HNO_3 using the method evolved by Ghouse & Yunus (1972). The epidermal peels will be stained with Heidenhain's iron, haematoxylin and Safranin/Bismark brown alone or in combination (Johansen, 1940) and dehydrated in ethanol series will be mounted in canada balsam. Dimensions of stomata and trichomes will be measured with an ocular micrometer scale. Stomatal index (SI) will be calculated by the Salisbury's (1927) formula.

$$SI = \frac{S}{S + E} \times 100$$

where S and E represent number of stomata and epidermal cells in a given microscopic field. Counts of stomata and epidermal cells will be made on a compound microscope at suitable magnifications.

B.

The collected samples will be fixed in FAA and transferred to an alcoglycerol for softening and preservation. To study the anatomical variation within root and stem, fibre and vessel elements will be macerated by treating with hot HNO_3 to the slices of wood from the third internode and the slices of root from 1 cm. below the ground. This treatment results in separating the elements which become free and loose (Ghouse & Yunus, 1972). Out of the macerated elements, 50 vessels members, 100 fibres per sample will be measured on a random basis with the aid of an ocular micrometer scale. 12 Um thick transverse sections will be obtained on a Reichert's sliding microtome from the third internode of stem and root samples collected from different experimental sites. In order to estimate average width, relative abundance and proportion of cortex vasculature and pith region, the sections will be stained with Heidenhain's iron, haematoxylin and safranin/Bismark Brown alone or in combination (Vohansen, 1940) and dehydrated in ethanol series will be mounted in canada balsam. To calculate the variation in the relative proportion of various root and stem components the method based on the weight of paper cuttings of the camera lucida drawings made on tracing paper of uniform thickness (Ghouse & Iqbal, 1975) will be adopted.

Biochemical studies:

Since there is a close correlation between the amount of chlorophyll and the rate of photosynthesis, the primary productivity may be predicted on the basis of chlorophyll estimation (Billore & Mall, 1975; Kumar et al., 1980).

The chlorophyll content of leaves of the selected perennials will be estimated according to Arnon (1949) using fresh leaf samples. The chlorophyll of one gram fresh leaves will be extracted in 80% acetone in the forenoon. The fresh samples of leaves in three replicates will be soaked in small amounts of 80% acetone, crushed gently with mortal and pestle to extract the chlorophyll and filtered with Whatman's filter paper No. 1. The volume of the chlorophyll will be made 100 ml by adding 80% acetone (80:20 acetone & distilled water). The absorption at 645 nm and 663 nm of the pigment will be read on a spectrophotometer. The chlorophyll concentration in mg per gram of fresh sample will be calculated using the following formulae given by Arnon (1949).

Chlorophyll a per gram of fresh tissue

$$= 12.7\ (D\ 663) - 2.69\ (D\ 645) \times \frac{V}{100 \times W}$$

Chlorophyll b per gram of fresh tissue

$$= 22.9\ (D\ 645) - 4.68\ (D\ 663) \times \frac{V}{100 \times W}$$

$$\text{Total chlorophyl} = 20.2\ (D\ 645) + 8.02\ (D\ 663) \times \frac{V}{1000 \times W}\ \text{mg/gram fresh leaf.}$$

where

D 645 = value of optical density at 645 absorption spectra

D 663 = value of optical density at 663 absorption spectra

V = volume of extract

W = leaf portion weight

Estimation of N.P.K.: Relative proportions of N, P and K in the leaves will be estimated at different stages of growth on dry weight basis. Normal leaves from each plant will be taken randomly, dried in an oven for 24 hours and powdered fine with 72 mesh screen. The powder thus obtained will be kept at 70°C overnight before digestion and analysis which will be accomplished by the methods of Lindner (1944) as follows:

Digestion of sample: 100 mg dry powder of leaves will be taken in a 50 ml Kjeldahi flask. Two ml of pure H_2SO_4 (BDH) will be added and the mixture be heated for about two hours to dissolve the powder. This heating with the acid will turn the content black. After cooling the flask for about 15 minutes, 0.5 ml of chemically pure 30% hydrogen peroxide will be added drop wise. The solution will be heated again for about 30 minutes, until it turns light yellow in colour. The it will be cooled. With 3-4 drops of hydrogen peroxide, it will be reheated for about 15 minutes to get a clean extract. Excess of hydrogen peroixde will be avoided which would otherwise oxidise the ammonia in the absence of organic matter. The peroxide digested material will be transferred to 100 ml volumetric flask with three or four washings with DDW and the volume be made up to mark. This will serve as a stock solution for the estimation of N, P and K.

Estimation of nitrogen: According to Lindner (1944), a 10 ml aliquot of the peroxide digested material will be transferred to a 50 ml volumetric flask. Two ml of 2.5 N sodium hydroxide will be added to neutralise the excess of the acid partially. To prevent the turbidity, one ml of 10% sodium silicate will be added to the flask and the volume be made up. In a 10 ml graduated test tube, 5 ml of aliquot of this solution will be taken and 0.5 ml of Nessler's reagent will be mixed thoroughly. The final volume will be made up with DDW and kept for about five minutes for the maximum colour development. This solution will be taken in a colorimetric tube and the optical density will be measured at 525 nm. A blank will also be run simultaneously during determination. A standard curve of known dilution of ammonium sulphate solution will be plotted. Reading of each sample will be compared with this calibration curve.

Estimation of phosphorus: Phosphorus will be estimated by the method of Fiske and Subbarow (1925). In a 10 ml graduated tube, 5 ml of aliquot will be taken and 1 ml of molybdate reagent will be added carefully, followed by 1,2,4, amino nepthol sulphonic acid (0.4 ml). This acid will turn the contents blue. The volume will be made up and the solution be allowed to stand for about 5 minutes for the maximum colouration. Later it will be transferred to a calorimetric tube and the optical density will be read at 620 nm. A blank will be run for each determination. A calibration curve will be prepared by using known dilutions of a standard monobasic potassium phosphate solution.

Estimation of potassium: Potassium will be estimated using a flame photometer. A blank will be run side by side. The readings will be compared with a calibration curve plotted for different dilutions of a standard potassium sulphate solution.

Statistical analysis:

The data collected on different parameters pertaining to the foliar study carried out at the different study sites will be statistically analysed as under to determine the degree of authenticity of results.

Mean (X): The arithmatic mean, or simple mean or the so called average value may be easily computed by Taking the sum of a number of values (x_1, x_2, x_3 .... and so on) and dividing by the total number of values (N) involved: thus,

$$\bar{X} = \frac{(X_1 + X_2 + X_3 \ldots\ldots\ldots\ldots Xn)}{N} \quad \text{or,} \quad \bar{X} = \frac{X}{N}$$

where, X_1, X_2, X_3 .... Xn = observations

N = number of observation.

Standard Deviation (or S.D.): Standard deviation is a measure of fluctuations in a sample produced as a result of chance factor's of sampling from the same population. It may be calculated by the following formula.

S.D. for large sample:

$$S.D. = \pm\sqrt{\frac{(\bar{X} - X_1)^2 + (\bar{X} - X_2)^2 + \ldots\ldots (X - Xn)^2}{N}}$$

S.D. for small samoles:

$$S.D. = \pm\sqrt{\frac{(X - X_1)^2 + (X - X_2)^2 + \ldots\ldots (\bar{X} - Xn)^2}{N - 1}}$$

where $\bar{X}$ = Mean of the observations involved

X_1, X_2, X_3 .... = observations.

N = Number of observations.

Standard Error ($\bar{X}$ or SE) of Means: S.E. of mean is a measure of reliability of a sample mean as an estimate of the polution mean. It will be computed by using the following formula:

$$S.E. = \pm\sqrt{\frac{S.D. \text{ of sample}}{n - 1}}$$

Standard Error of the Difference of Sample Means (S.E.D.): It may be defined as the standard deviation computed from the difference between a large number of pairs of means of randomly selected samples from two populations. Standard error of the difference of two samoles viz. $\bar{X}$ and $\bar{Y}$ = of two different populations becomes important when it is to be judged whether or not they differ significantly. It will be computed as follows:

$$S.E.D. = \sqrt{\frac{(S.D_1)^2}{n_1} + \frac{(S.D_2)^2}{n_2}}$$

where, S.D. 1 = S.D. of one sample

S.D. 2 = S.D. of other sample

n_1 = No. of observation in one sample

n_2 = No. of observation in other sample

Coefficient of variation (C.V.): This measures the relative magnitude of variation present in observations relative to the magnitude of their arithmetic mean. It is defined as the ratio of S.D. to arithmetic mean expressed as a percentage.

eg. $$C.V = \frac{S.D.}{\bar{X}} \times 100$$

where, S.D. = S.D. of the concerned sample or population

$\bar{X}$ = Arithmetic mean.

Test of significance: The test of significance is a device to findout whether or not an observed pair of means differs significantly from each other, or this difference is just a result of chence influence. It is a device, a criterion, to arrive at a judgement and confidence about the validity of a result. The following two tests will be applied for the purpose.

Student t-test: It will be applied to test the significance of the difference between the two sample means (if any), each sample collected from the two study sites.

The following formula will be used to compute t-value which will be compared with the table value of 't' at their particular degrees of freedom. If calculated 't' value exceeds the table value the difference between the two samples will be treated as significant, otherwise the difference will eb attributable to chance factor.

$$t = \frac{\underline{\text{Difference of two sample means}}}{\text{Standard error of the difference}}$$

or

$$t = \frac{\bar{X}_1 \text{ ------ } \bar{X}_2}{\sqrt{\frac{(S.D._1)^2}{n_1} + \frac{(S.D._2)^2}{n_2}}}$$

where, $\bar{X}_1$ = Arithmetic mean of one sample

$\bar{X}_2$ = Arithmetic mean of the other sample

SD_1 = S.D. of one sample

SD_2 = S.D. of other sample

n_1 = No. of observation of one sample

n_2 = No. of observation of other sample

Degree of freedom (D.F.): Degree of freedom, to be applied to the number of data particularly in t-test will be calculated as follows:

$$D - F = n_1 + n_2 - 2$$

where, n_1 = No. of observation of one sample

n_2 = No. of observation of other sample.

For its use in the least significant difference analysis (L.S.D.).

$$DF = (T \times R) - 1 - (R - 1) + (T - 1)$$

where T = Number of treatments

R = Number of observations

Least Significance difference (L.S.D.): This test is applied to compare all pairs of means. The following formula will be used to calculate L.S.D.

$$L.S.D. = \sqrt{\frac{2 \times MSE}{r}} \times t - \text{Value}$$

where, MSE = Estimated varience of error

r = No. of replicates.

$$MSE = \frac{SSQE}{(r-1)(t-1)}$$

where, SSQE = Error sum of squires

r = Number of replicates

t = Number of treatments.

SSQE = SSQT - (SSQr - SSQt)

Where, SSQT = Total sum of squires

SSQr = Sum of squares between replications

SSQt = Sum of squares between treatment

SSQT = Sum of the squares of each value and substracted from it correction factor (C.F.)

where, $C.F. = \dfrac{(Total)^2}{r \times t}$

$$SSQr = \frac{\text{sum of squares of replications}}{\text{No. of treatments} - 1} - C.F.$$

$$SSQt = \frac{\text{sum of squares of treatment}}{\text{No. of replications} - 1} - C.F.$$

<u>Correlation Coefficient (r)</u>: This is a statistical measure which indicates both nature and degree of relationship between two measurable characteristics, say height (X-cm) and yield (y-gm). It will be compouted as follows:

$$r = \frac{N \; XY - (\; X) \; (\; Y)}{\sqrt{(N \; X^2 - (\; X)^2 \quad (N \; Y)^2 - (\; Y)^2}}$$

where, X = observations on height

Y = observation on yield.

OR

$$r = \frac{(X - \bar{X}) \; (Y - \bar{Y})}{\sqrt{(X - \bar{X})^2 \; (Y - \bar{Y})^2}}$$

where, X = observation on one character

$\bar{X}$ = Arithmetic mean of all X observation

Y = Observation on other character

$\bar{Y}$ = Arithmetic mean of all Y observation.

A correlation coefficient may very from - 1 (perfect negative correlation) to +1 (perfect positive correlation).

Any value close to zero would denote a lack of correlation or a relatively week correlation.

Coefficient of Determination (d): It is a derivative of correlation coefficient when expressed in percentage. It shows percent variation

$$d = (r)^2$$

or $$d = 100\ (r)^2 \text{ - expressed in percentage}$$

where d = coefficient of determination

r = correlation coefficient

Linear Regression: Correlation coefficient elucidates the nature and degree of relationship between two characteristics. Due to such correlation when variation in one variable brings in acompanying changes in the other, it enables us to predict the value of one variable from the knowledge of other.

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